International Journal of Mechanical and Production
Engineering Research and Development (IJMPERD)
ISSN (P): 2249-6890; ISSN (E): 2249-8001
Vol. 8, Issue 2, Apr 2018, 495-508

MECHANICAL BEHAVIOR OF AL 7075 REINFORCED WITH AL_2O_3 AND SIC NANO PARTICLES FABRICATED BY STIR CASTING METHOD

S. SURESH[1], G. HARINATHGOWD[2] & M. L. S. DEVA KUMAR[3]

[1]*Research Scholar, Department of Mechanical Engineering, Jawaharlal Nehru Technological University, Ananthapuramu, Andrapradesh, India*

[2]*Professor, Department of Mechanical Engineering, Madanapalle Institute of Technology and Science, Chittoor, Aadrapradesh, India*

[3]*Vice Principal & Professor, Department of Mechanical Engineering, Jawaharlal Nehru Technological University, Ananthapuramu, Andrapradesh, India*

ABSTRACT

Demand increases in a global range of the new brand products at national and International level. The metal matrix Nano composites are highly useful in many applications such as aerospace, automobile, military and various other architectural applications. In my research, I have used three different hybrid compositions, namely Nano Al_2O_3 (20-30nm), Nano-SiC (50nm) and micro Mg which uses 1 Weight %. Magnesium is to improve the wet ability of Al_2O_3 and SiC particles in the Al matrix. The compositions are carried out simultaneously 1.0, 2.0, 3.0, and 4.0 Weight %. Of Nano Al_2O_3 and Nano SiC. The cast specimens undergo the tests like heat treatment, micro-structural evaluation, density, and porosity measurements, tensile, hardness, Impact, EDX along with SEM. SEM images expose that the Nano particles, fairly distribute and achieve fine grain microstructure in the matrix. The outcomes reveal the reinforcement of Nano particles in Al 7075 matrix substantially increases the Mechanical properties when compared to base metal.

KEYWORDS: Al7075, Stir Casting, Al_2O_3, SiC & Nanocomposites

Received: Jan 25, 2018**; Accepted:** Feb 14, 2018**; Published:** Mar 07, 2018**; Paper Id.:** IJMPERDAPR201858

Original Article

INTRODUCTION

Aluminum alloy composites are useful in the aerospace, the automobile, the defense as well as architectural applications. The composites have unique properties. In most cases, various ceramic powders such as boron carbide, zirconia, aluminum oxide (Al_2O_3) and silicon carbide (SiC), are added to the aluminum alloy to increase the Mechanical and Tribological behavior [1]. The hybrid composites have been developed recently with improved mechanical properties. The present research study reported that the consistent mixing, as well as perfect vetting by using the parameters such as time, speed and temperature [2]. Among many manufacturing procedures, the traditional stir casting is an enticing approach to producing AMC which is relatively affordable. In various particles, silicon carbide as well as Al_2O_3 is chemically appropriate for lightweight aluminum and also create a suitable bonding with the matrix [3].

The objective of the present investigation is to analyze the mechanical behavior of Al7075 alloy enhanced with three types of fragments viz. Sic (50nm), Al_2O_3 (20-30 nm) and also 1 Weight % of Mg (micro). The tensile, hardness and toughness results are far better when compared with a non-reinforced matrix product. The tensile strength of the metal matrix Nanocomposite specimens examined under Universal testing equipment, and a

hardness examination is carried out on a Brinell hardness machine. The microstructures of the samplings are checked out by using the Optical Microscopic lens, Scanning Electron microscopic lens (SEM) and EDS [4].

EXPERIMENTAL WORK

Material Selection

Al 7075 takes as the base metal, and it purchased from Mr. Aluminium Enterprise, Bangalore. The chemical compositions of aluminum alloy were analyzed using optical emission spectrometer (SHIMADZU-JAPAN, Model: TDA-700) at Chennai. Table 1 shows the chemical composition of Al7075. The secondary phase materials selected is Al_2O_3 (20-30 nm), SiC (50nm) and Mg (microns).

Table 1: Chemical Composition of Al7075 by Wt. %

Element	Fe	Si	Mn	Cr	Cu	Ti	Zn	Mg	Others	Al
% of weight	0.198	0.052	0.055	0.195	1.458	0.047	5.989	2.151	0.025	Reminder

Figure 1 (a): Stir Casting Setup

Figure 1 (b): Solidified Composite

MELTING PROCEDURE

The stir casting equipment used for this research which locates at Karunya University, Coimbatore used for this experimental work. The size of the mold used for casting is 100x100x10 mm [5]. The raw materials used for this work are as follows:

- Metal matrix-Aluminium alloy (Al-7075)
- Reinforcement materials - Silicon carbide particles (50nm) and Aluminium oxide (20-30nm)
- Surfactant- Magnesium powder (microns)
- Crucible- Graphite (size no. 6)

Table 2: Stir Casting Furnace Specifications

Make SWAMEQUIP	
Capacity	2Kg
Operating temperature	100-1500°C
Operating voltage	440 V, 3 Phase

Aluminum 7075 alloy melts in a graphite crucible in an electrical resistance furnace. The furnace at the 750°C temperature, and the pre-heated Nano Al_2O_3, Nano SiC (900°C) and wetting agent 1 Weight % of Mg slowly added to the graphite crucible [6]. Then, the slurry is mechanically stirred using a three-bladed stainless-steel stirrer continuously for 5 minutes at 650 rpm (Semi-solid stirring). In the meanwhile, the composite slurry is poured into the preheated permanent

mold and allowed it to solidify. Finally, the cast specimen removed after 2 minutes. The same procedure fabricated aluminum matrix composites with different weight percentages (1, 2, 3 and 4wt. %) of Nano Al_2O_3 and Nano SiC. After completion of the process, cast specimens cut as per ASTM standards [7].

Table 3: Process Parameters during STIR Casting

Stirring speed	650 rpm
preheat temperature	900^0c
Stirring temperature	750^0C
Stirring time	5 minutes

(c) **(d)**
Figure 1: (c) Pouring into Dies **(d) Final Cast Specimens**

HEAT TREATMENT

T6 heat treatment is used for aluminum alloys to improve their mechanical properties. T6 heat treatment of Nano Al_2O_3 in addition to Nano Sic reinforced Al7075 composite samplings, where heat treatment is done at 530^0C for 2 hrs, followed by water quenching, as well as aging treatment did at 200^0C for 6 hrs. Before Heat treatment, cast specimens initially cut as per ASTM dimensions by using Wire cut Electric discharge machine [7, 8].

RESULTS & DISCUSSIONS

Density and Porosity Measurement

Density plays an essential function in composite material research. As this material having a range in the automotive sector and also in the aerospace field, they need to be lightweight. Incorporating some strengthened materials like Nano aluminum oxide as well as Nano silicon carbide reduces the density of composites. The Archimedes principle that is dividing the mass of a specimen by the quantity displaced by that sample in the water beaker is to calculate density [9, 10]. Porosities determine the difference between theoretical density and experimental density.

$$\rho_c = \frac{1}{\left(\frac{W_{Al}}{\rho_{Al}}\right) + \left(\frac{W_{Al_2O_3}}{\rho_{Al_2O_3}}\right) + \left(\frac{W_{SiC}}{\rho_{SiC}}\right) + \left(\frac{W_{Mg}}{\rho_{Mg}}\right)}$$

% Porosity= (Theoretical density - Experimental density) **/** (Theoretical density) X 100

Table 4: Density and Porosity for Different Compositions

ALLOY	Theoretical	Experimental	% Porosity
Pure AL7075	2.7	2.6107	3.307
1%Al_2O_3+1%SiC+1%Mg	2.6982	2.6321	2.4497
2%Al_2O_3+2%SiC+1%Mg	2.7113	2.6688	1.5675
3%Al_2O_3+3%SiC+1%Mg	2.7241	2.6841	1.4683
4%Al_2O_3+4%SiC+1%Mg	2.738	2.6986	1.4390

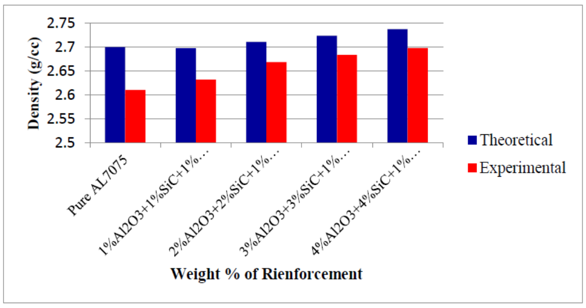
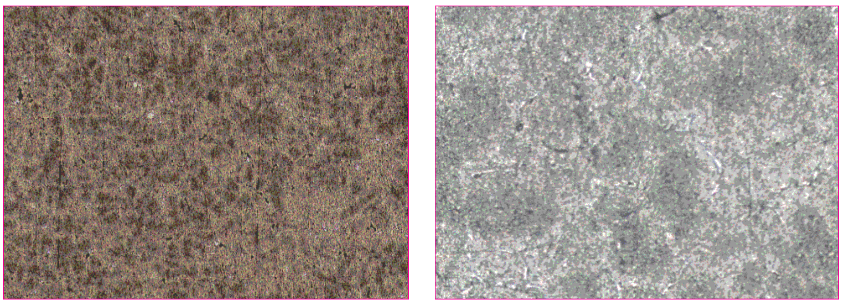


Figure 2: Density and Porosity of Different Compositions

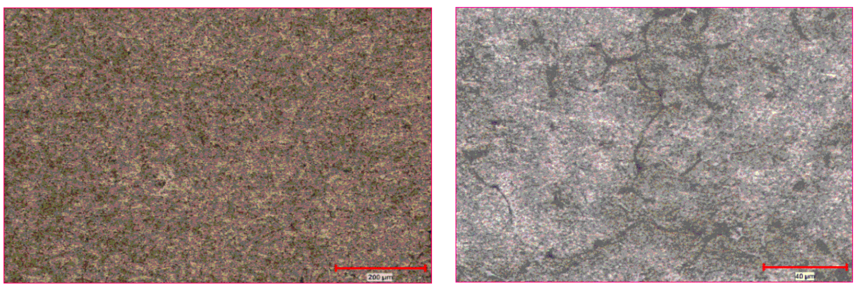
Microstructure Evaluation

The Optical microscopic images reveal that there is a uniform distribution of Nano Al_2O_3 and Nano SiC reinforcement particles in Al matrix [11]. There is an observation of the lower level of porosity from the micro structural photographs noticed additionally. From the microphotographs, it seems to be a great bonding between the matrix as well as the reinforcement. Microscopy of cast specimens by using an Optical microscope shows the following results.



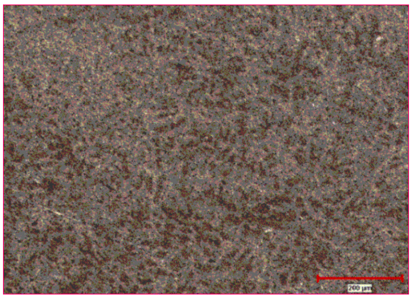
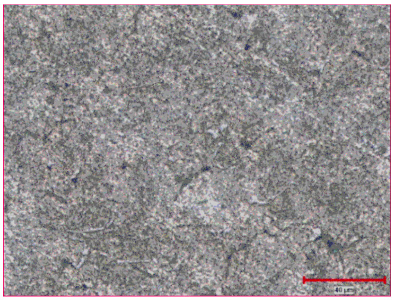
(a) **(b)**

Figure 3: Optical Microscopic Images of Pure Al 7075 (a) 100 X b) 500X



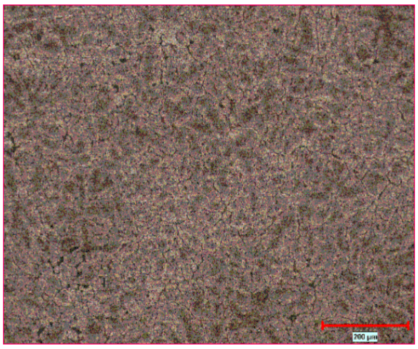
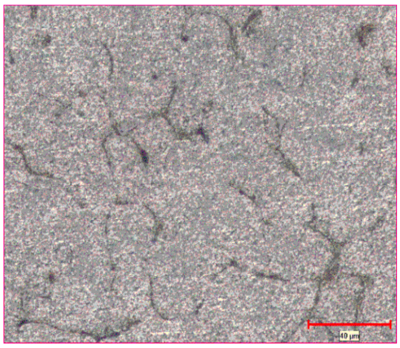
(c) **(d)**

Figure 3: Optical Microscopic Images of 1% Al_2O_3 + 1% SiC + 1% Mg (c) 100X(d) 500X

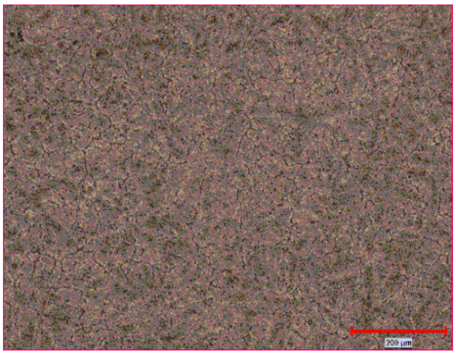
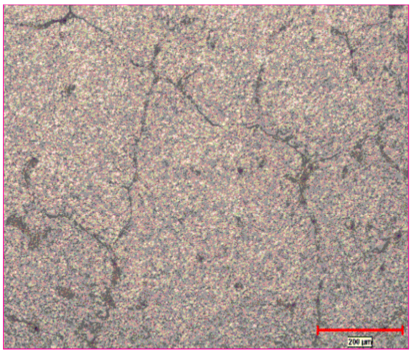
(e) (f)

Figure 3: Optical Microscopic Images of 2% Al_2O_3 + 2% SiC + 1% Mg (e) 100X (f) 500X

(g) (h)

Figure 3: Optical Microscopic Images of 3% Al_2O_3 + 3% SiC + 1% Mg (g) 100X (h) 500X

(i) (j)

Figure 3: Optical Microscopic Images of 4% Al_2O_3 + 4% SiC + 1% Mg (i) 100X (j) 500X

MECHANICAL PROPERTIES

Tensile Test

There is an assessment of tensile properties of the Al 7075 alloy and composites by performing a tensile test on the universal testing machine of 500 KN capacities. By using a generated software program during the tests displayed stress and strain information and noted the same. And this report helped for further evaluation. There are the preparation of samplings as per ASTM E8 [12] standards for the testing of the product.

Figure 4: Universal Testing Machine

Figure 5: Samples of the Tensile test

Table 5: Tensile Strength

Alloy	Yield Strength(N/mm^2)	UTS(N/mm^2)	% Elongation
Pure AL7075	137	268	4.2
1%Al_2O_3+1%SIC+1%Mg	149	254	2.3
2%Al_2O_3+2%SIC+1%Mg	152	376	1.8
3%Al_2O_3+3%SIC+1%Mg	159	412	1.5
4%Al_2O_3+4%SIC+1%Mg	165	463	1.1

Yield Strength

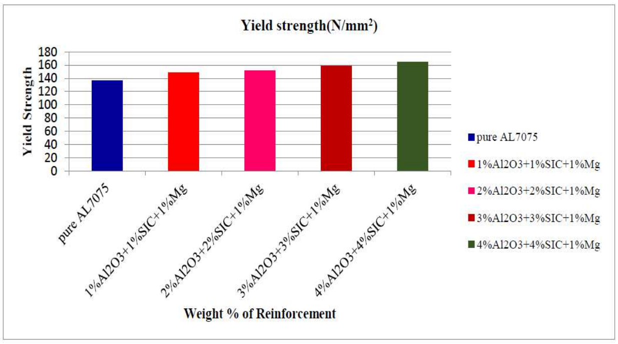


Figure 6: Yield Strength for Different Composition

As shown in Figure 6. Above outcomes predict that the increase in weight percentage of reinforcement leads to Yield Strength rising. It takes place due to the dispersion of Nano SiC and Nano Al_2O_3 which produce hindrance to a dislocation motion. To relocate this problem (plastically yielding the product or deforming), a larger stress should be used [13]. It results in a rise in tensile strength of Al 7075 reinforced alloys.

Ultimate Tensile Strength

As shown in Figure 7 results predict that as the increase in the reinforcement Weight % leads to increase of ultimate tensile strength. It happens due to the dispersion of Al_2O_3 and Sic that create a hindrance to dislocation motion. This may result in an increase in tensile strength of Al7075 reinforced alloy.

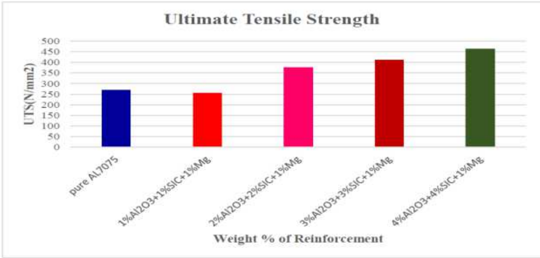


Figure 7: Ultimate Tensile Strength of Different Compositions

Percentage of Elongation

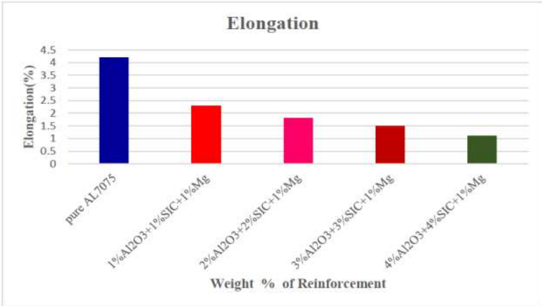


Figure 8: Elongation of Different Compositions

As shown in above Figure 8 outcomes revealed that by adding Nano Al_2O_3 and Nano SiC percentage elongation is decreased. That shows a decrease in elasticity of the composite.

Hardness Test

Macro Hardness Test (Brinell hardness) ASTM E10-17

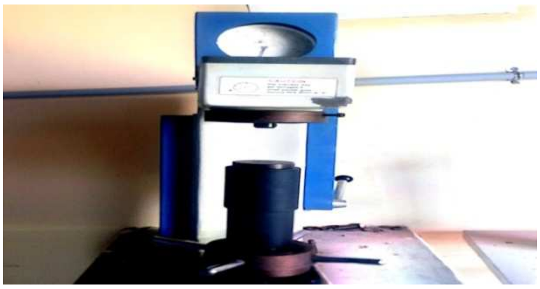


Figure 9: Brinell Hardness

The Brinell test has frequently used the method to examine the cast samplings [14]. Throughout the assessment tungsten ball indenter with diameter 10 mm by applying load for 10 seconds on five samples with three trails as shown in Table 6. From Figure 10, it is concluded that hardness of example 2 is higher when compared to other samples.

Table 6: Macro Hardness Test

Sample No	Sample Name	Hardness			Mean
		Brinell Hardness			
	Al 7075	Trail 1	Trail 2	Trail 3	Hardness
1	Pure	57.3	57.5	58.9	57.9
2	1%Al_2O_3+1%SiC+1%Mg	60.8	64.9	62.1	62.6
3	2%Al_2O_3+2%SiC+1%Mg	60.1	57.3	58.4	58.6
4	3%Al_2O_3+3%SiC+1%Mg	63.7	58.3	53	58.3
5	4%Al_2O_3+4%SiC+1%Mg	63	60.8	62.3	62.0

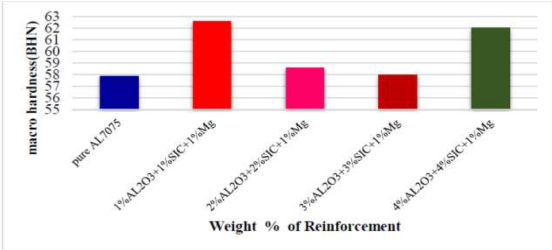


Figure 10: Macro Hardness for Different Compositions

Micro Hardness Test (Vickers hardness) ASTM E 92-17:

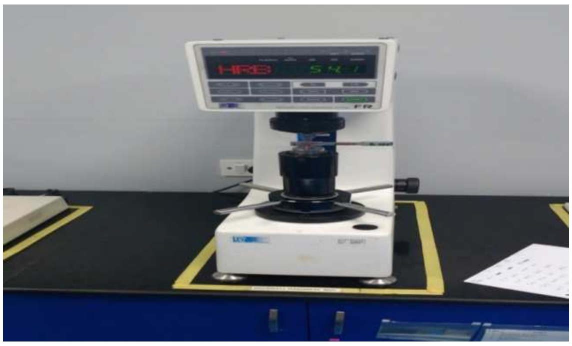


Figure 11: Vickers Micro Hardness

There is an evaluation of the Microhardness of the composite specimen by using the Vickers microhardness machine. A load of 50 grams for ten sacks applied on samplings. There is the performance on an examination at 5 various locations where the average value was taken. Table 7 reveals that by incorporating Nano Al_2O_3 and Nano SiC, the hardness values increase more when compare to the Parent metal as shown in Figure 12.

Table 7: Micro Hardness

Sample No	Sample Name	Hardness			Mean
		Vickers Hardness			
	Al 7075	Trail 1	Trail 2	Trail 3	Hardness
1	Pure	98	85	89	90.6
2	1%Al_2O_3+1%SiC+1%Mg	108	120	115	114.3
3	2%Al_2O_3+2%SiC+1%Mg	110	102	105	105.6
4	3%Al_2O_3+3%SiC+1%Mg	110	115	107	110.6
5	4%Al_2O_3+4%SiC+1%Mg	107	103	105	105

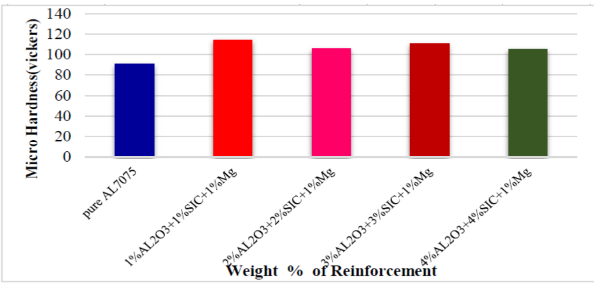


Figure 12: Micro Hardness for Different Compositions

Scanning Electron Microscopy

SEM analysis uses efficiently in microanalysis and also failure evaluation of materials. Scanning electron microscopy executes at high magnifying, produces high-resolution images and precisely measures very tiny objects.

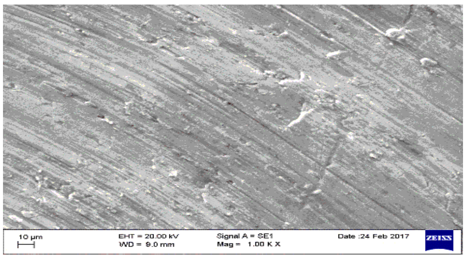


Figure 13: Pure Al7075

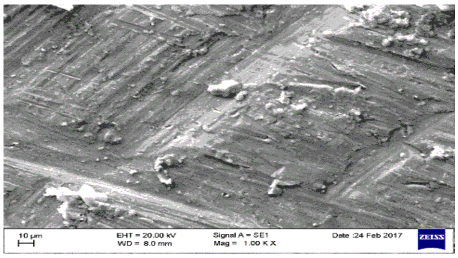


Figure 14. Al7075 + 1% Al_2O_3 + 1% SiC + 1% Mg

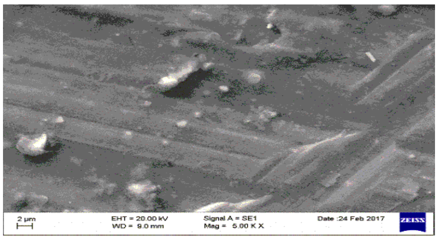


Figure 15: Al7075 + 2% Al_2O_3 + 2% SiC + 1%Mg

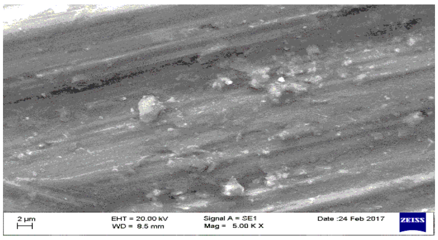


Figure 16: Al7075 + 3% Al_2O_3 + 3% SiC + 1% Mg

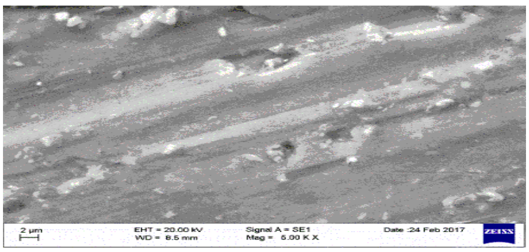


Figure 17: Al7075 + 4% Al_2O_3 + 4% SiC + 1%Mg

Figures 13, 14, 15, 16, 17 are presented with the microphotographs of Cast Al 7075/ Al_2O_3 and silicon carbide composites respectively. From figures 13, 14, 15, 16, 17 it can be noticed that the distributions of reinforcements in the metal matrix are relatively uniform. Additionally, these figures expose the uniformity of the cast composites. The microphotography also clearly shows the increased file contents of the composites [15]. Flaws are also seen in the microstructure.

Energy Dispersive X-ray Spectroscopy

Energy dispersive spectroscopy (EDS) is a micro evaluation method. The primary function of EDS is to disperse of Al_2O_3 and Sic Nanoparticles in Al melt achieved by stir casting method.

Table 8: Elemental Composition of Pure Al7075

Element	Weight %	Atomic %
CK	16.44	31.68
Mg K	2.35	2.24
Al K	74.09	63.54
Cu K	1.78	0.65
Zn K	5.34	1.89
Total	**100.00**	

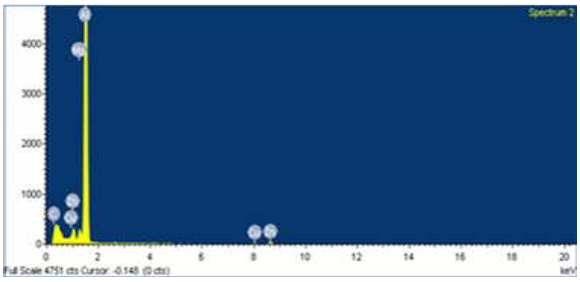


Figure 18: Pure Al7075

Table 9: Elemental Composition of 1% Al_2O_3 + 1% Sic

Element	Weight %	Atomic %
C K	29.82	46.47
OK	13.07	15.29
Mg K	1.29	0.99
Al K	51.51	35.73
Si K	0.71	0.48
Zn K	3.30	1.03
Total	**100.00**	

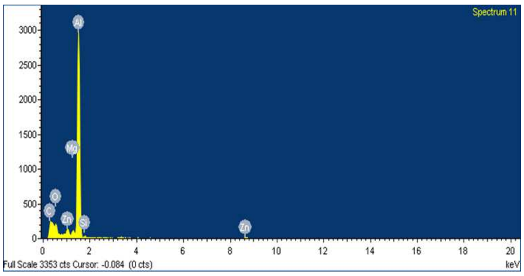


Figure 19: Al7075 + 1% Al_2O_3 + 1% Sic + 1%Mg

Table 10: Elemental Composition of 2% Al_2O_3 + 2% Sic

Element	Weight %	Atomic %
C K	28.37	45.77
OK	9.69	11.74
Mg K	1.05	0.83
Al K	54.55	39.17
Si K	1.54	1.06
Zn K	4.80	1.42
Total	**100.00**	

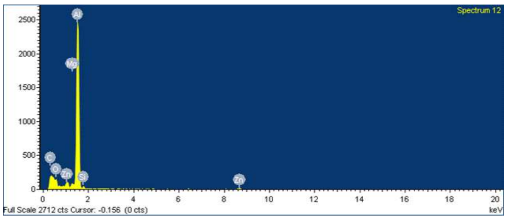


Figure 20: Al7075 + 2% Al_2O_3 + 2% Sic + 1% Mg

Table 11: Elemental Composition of 3% Al_2O_3 + 3% Sic

Element	Weight %	Atomic %
C K	31.74	52.01
Mg K	1.54	1.25
Al K	62.22	45.38
Zn K	4.50	1.35
Total	**100.00**	

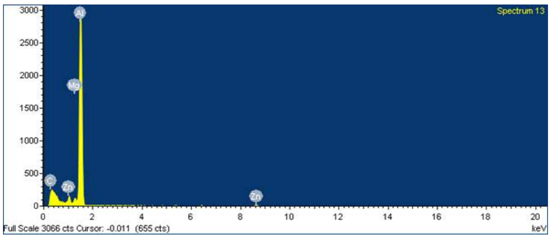


Figure 21: Al7075 + 3% Al_2O_3 + 3% SiC + 1% Mg

Table 12: Elemental Composition of 4% Al_2O_3 + 4% SiC

Element	Weight %	Atomic %
C K	31.28	51.79
Mg K	1.68	1.37
Al K	61.11	45.03
Zn K	5.93	1.80
Total	**100.00**	

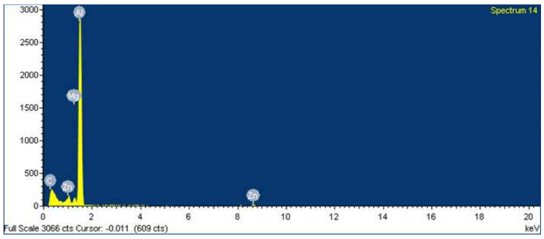


Figure 22: Al7075 + 4% Al_2O_3 + 4% SiC + 1% Mg

The elemental evaluation was executed in an EDX system affixed to the scanning electron microscope lens to check out the chemical compositions of 1.0, 2.0, 3.0 and 4 Weight % of Al_2O_3 as well as Sic. The EDX photographs shown in Figures 19, 20, 21, 22 from the photographs it reveals that the aspects which are included the mix exist, as their peaks are clearly visible.

CONCLUSIONS

In the present work, Al7075/Al_2O_3/ Sic aluminum metal matrix composites prepared by the stiring casting Method and the impact of Nano Al_2O_3 and Nano SiC particulate content on mechanical properties of the prepared AMMCs were investigated. The outcomes could be summarized as follows:

- The outcomes revealed that incorporation of Nano SiC /Al_2O_3 reinforced materials is superior to base Al 7075 alloy in comparison of tensile strength and hardness.
- Diffusion of Nano SiC/Al_2O_3 particles in the aluminum matrix enhances the hardness of the matrix material.
- It indicates that the percentage of elongation tends to reduce by increasing reinforcement weight percentage, which verifies that silicon carbide and also alumina addition improves brittleness
- It shows up from this research that Ultimate tensile and Yield strength values begin to rises with raising a weight portion of SiC as well as Al_2O_3 in the matrix
- The Hardness improves after enhancement of SiC, Al_2O_3 particles in Metal matrix.
- SEM and EDX results revealed the presence of Al_2O_3, SiC and Mg particles in the alloy matrix distributed evenly throughout in the MMNC hence strengthening the resulting composite.
- Stirrer design, stirring time and speed and preheating temperature are the important parameters.

SCOPE OF FUTURE WORK

- The research work is extended further by varying geometrical angle of Stirrer and stirring speed.
- The heat treatment can be done to improve the properties.
- Varying reinforcement Grain Size can vary results.

ACKNOWLEDGEMENTS

The author, Suresh, wishes to thank the Department of Mechanical Engineering, Jawaharlal Nehru Technological University, Ananthapuramu, India for providing facilities and necessary support in conducting experiments and also Prof. G. Harinath Gowd, Department of Mechanical Egg., MITS, Madanapalli, India, and Viceprincipal and the Prof. M. L. S. Deva Kumar Dept. of Mechanical Egg., JNTUA, Ananthapuramu India, for their support and discussion in the research work.

REFERENCES

1. *Baradeswaran, S. C. Vettivel, A. ElayaPerumal, N. Selvakumar, R. Franklin Issac (2014). Experimental investigation on mechanical behavior, modeling, and optimization of wear parameters of B4C and graphite reinforced aluminum hybrid composites. Materials and Design, 63, 620-632.*
2. *J. H. Shin, H. J. Choi, D. H. Bae. (2014). the structure and properties of 2024 aluminum composites reinforced with TiO2 nanoparticles. Materials Science and Engineering, 607, 605-610.*
3. *J. S. Sureshbabu, P. K. Nair, C. G. Kang. (2007). Fabrication and characterization of aluminum-based nano-micro hybrid metal matrix composites.16th International conference on composite materials, 1-5.*

4. *J Hashim, L Looney, and M. S. J Hashmi. (1999). Metal matrix composites: production by the stir casting method‖ Journal of Materials Processing Technology, 92–93, and 1–7.*

5. *X. P. Zhang, L. Ye, Y. W Mai, G. F. Quan, W. Wei (1999). Investigation on diffusion bonding characteristics of SiC particulate reinforced aluminum metal matrix composites (Al/SiCp-MMC). Composites Part A. applied science and manufacturing, 30, 1415-1421.*

6. *N. Sarada, P. L. SrinivasaMuthy, G. Ugrasen. (2015). Hardness and wear characteristics of Hybrid Aluminium Metal Matrix Composites produced by stir casting technique. Materials Today: Proceedings, 2, 2878-2885.*

7. *S. M. Choi, H. Awaji. (2005). Nano Composite-a new material design concept. Science and Technology of Advanced Materials, 6, 2-10.*

8. *Kenneth KanayoAlaneme, KazeemOladitiSanusi. (2015). Microstructural characteristics, mechanical and wear behavior of aluminum matrix hybrid composites reinforced with alumina, rice husk ash, and graphite. Engineering Science and Technology, an International Journal, 18, 416-422.*

9. *Pardeep Sharma, Satpal Sharma, Dinesh Khanduja. (2015). Production and some properties of Si3N4 reinforced aluminum alloy composites. Journal of Asian Ceramic Societies, 3, 352-359.*

10. *G. B. VeereshKuma, C. S. P. Rao, and N. Selvarajhttp, (2011). Mechanical and Tribological Behavior of Particulate Reinforced Aluminum Metal Matrix Composites – are view‖ Journal of Minerals & Materials Characterization & Engineering, Vol. 10, No.1, pp.59-91.*

11. *Weiping Chen, Yixiong Liu, Chao Yang, Dezhi Zhu, Yuanyuan Li. (2014). (SiCp+Ti)/7075 Al hybrid composites with high strength and large plasticity fabricated by squeeze casting. Materials Science and Engineering A, 609, 250-254.*

12. *Md. HabiburRahman, H. M. Maximum Al Rashed. (2014). Characterization of silicon carbide reinforced aluminum matrix composites. Procedia Engineering, 90, 103-109.*

13. *Jia-lei ZHAO, Jin-chuan JIE, Fei Chen, Hang Chen, Ting-ju LI, Zhi-qiang CAO. (2014). Effect of immersion Ni plating on interface microstructure and mechanical properties of Al/Cu bimetal. Trans. Nonferrous Met. Soc. China, 24, 1659-1665.*

14. *Kumar GBV, Rao CSP, Selvaraj N, Bhagyashekar MS. (2010). Studies on Al6061-SiC and Al7075-Al2O3 Metal Matrix Composites. Journal of Minerals and Materials Characterization and Engineering, 9, 43-55.*

15. *Sajjadi SA, Ezatpour HR, Parizi MT. (2012). Comparison of microstructure and mechanical properties of A356 aluminum alloy/Al2O3 composites fabricated by the stir and compo-casting processes. Mater Design, 34, 106-111.*